Application of track-etched nanopore in nanofluidic*

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Track-etched nanopores have broad application prospects in nanofluidic research fields, such as mimicking current rectification in ion channels, drug delivery systems, and micro-machines. Our research activities focus on current rectification in conical nanopores [1] and on electroosmotic pumps [2]. In both projects we use track-etched nanopores produced by irradiating thin polymer foils with GeV heavy ions followed by chemical etching.

Ion current rectification (ICR) in negatively charged conical nanopores is shown to be controlled by the electrolyte concentration gradient depending on the direction of ion diffusion. The degree of ICR is enhanced with the increasing forward concentration difference. An unusual rectification inversion is observed when the concentration gradient is reversely applied. A numerical simulation based on the coupled Poisson and Nernst Planck (PNP) equations is proposed to solve the ion distribution and ionic flux in the charged and structurally asymmetric nanofluidic channel with diffusive ion flow.

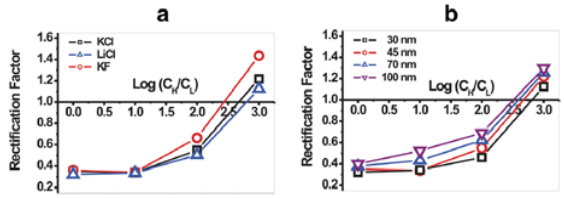

Figure 1: Model calculations qualitatively predict the trends in rectification inversion. (a) For KCl, LiCl, and KF, the degree of ICR initially decreases with increasing reverse concentration gradient. Under highest concentration gradient (1000-fold), rectification inversion occurs. (b) This trend depends on the diameter of the pore tip.

When the concentration gradient is reversely applied, an unusual rectification inversion is observed. Simulation results qualitatively describe the ICR behavior in conical nanopores suggested by experimental data and demonstrate the cooperation and competition between geometry-induced asymmetric ion transport and concentration-gradient driven ion flow (fig. 1). The present study improves our understanding of the ICR in asymmetric nanofluidic channels associated with the ion concentration difference. The diffusive and ion-rectifying of nanofluidic systems have promising use in constructing bio-inspired energy-conversion devices of high efficiency.

Track-etched polymer membranes are also used to realize low-voltage electroosmotic (EO) pumps. The diameter of the nanopores in polycarbonate (PC) and polyethylene terephthalate (PET) films was limited to 100 - 250 nm by adjusting the etching time. Low voltages (2–5 V) applied across the membrane results in high flow rates (fig. 2). The maximum normalized flow rate is as high as 0.12 ml min^{-1} V^{-1} cm^2, which is comparable to best values of previously demonstrated EO pumps. We attribute this to the unique properties of the track-etched nanopores.

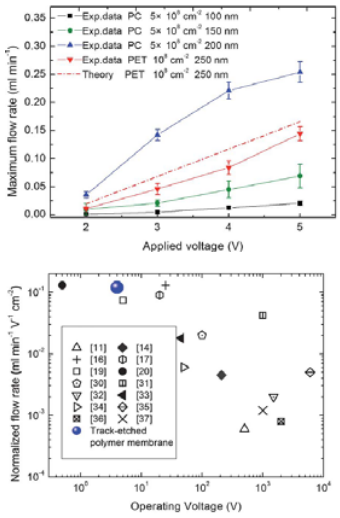

Figure 2: (top) flow rate versus applied voltage for EO pumps fabricated from three track-etched PC membranes with pore density of 10^8 cm^{-2} and pore diameters of 100, 150, and 200 nm in PC and 250 nm in PET membranes. (bottom) Comparison of the normalized flow rate obtained from track etched polymer membrane EO pump against flow rates reported in the literature.

We successfully demonstrated that the utilization of track-etched polymer membranes enables EO pumping to achieve flow rates that are higher than most values reported so far especially at low operating voltage. The simple and cost-effective fabrication of track-etched polymer membrane EO pumps makes them attractive for future applications in micro- or nanofluidic chips. These EO pumps are also capable of providing pressure/flow rate capacity sufficiently large for drug delivery applications and micro-electronics cooling.

[1] Liuxuan Cao, Wei Guo, Yugang Wang, and Lei Jiang, Langmuir 28 (2012) 2194.

[2] Ceming Wang, Lin Wang, Xiaorui Zhu, Yugang Wang and Jianming Xue, Lab Chip 12(2012) 1710.

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